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Marine Invaders in the Northeast: Rapid Assessment Survey of non-native and native marine species of floating dock communities, August 2003

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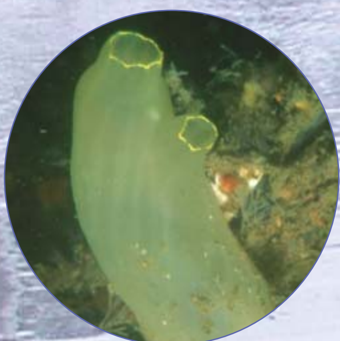
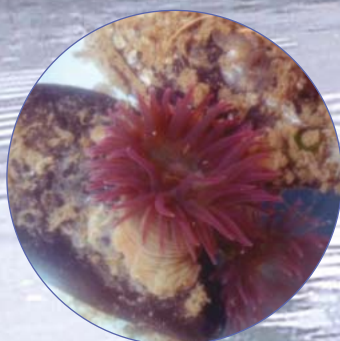


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Rapid Assessment Survey of Non-native and Native Marine Species of Floating Dock Communities

Report of the August 3-9, 2003 Survey

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Commandant William Lindsay, Coast Guard Pier and UNH Coastal Marine Laboratory, New Castle, New Hampshire; Geno Marconi, Hampton State Pier, Hampton, New Hampshire; Russ Vickers, Hawthorne Cove Marina, Salem, Massachusetts; Thomas Jacques, Rowes Wharf, Boston, Massachusetts; Lt. Mark Coady, Woods Hole Coast Guard Station, Woods Hole, Massachusetts; Captain George Benway, Massachusetts Maritime Academy, Bourne, Massachusetts; Carl Tripp, Tripps Marina, Westport, Massachusetts; William Slater, Allen Harbor Marina, North Kingstown, Rhode Island; Ann Souder, Newport Shipyard, Newport, Rhode Island; Ned Ahlborn, Brewer Yacht Club, Mystic, Connecticut; Bruce Kuryla, Milford Yacht Club, Milford, Connecticut; James Whitmore, Brewer Yacht Haven Marina, Stamford, Connecticut; Richard Smith, East Creek Marina, South Jamesport, New York; Jeff Bubb, Brewers Stirling Harbor Shipyard, Greenport, New York; Maggie Flanagan, South Street Seaport Museum, New York, New York; George Frame and Tom O'Connell, Great Kills Park, Staten Island, New York; Lois Schwarz, Snug Harbor Cultural Center, Staten Island, New York.

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Recreational boats docked at a marina. Photo credit: P. Dyrynda


Ryan Fisher and Jim Carlton examined the floating dock fouling communities. Photo credit: P. Dyrynda

INTRODUCTION

In his seminal book on *The Ecology of Invasions by Animals and Plants*, Elton (1958) laid the foundation for the science of biological invasions. He identified the importance of human-mediated vectors as means of transporting organisms to new locations and discussed invasions in the context of ecological impacts and evolutionary consequences. Elton even identified what needed to be done to prevent practical and ecological damages from invaders—keep them out, eradicate them, and if all else fails, manage them at acceptable levels. We have not been vigilant in applying this knowledge to marine ecosystems, although this is changing. Our ability to detect changes in numbers and rate of marine introductions depends on well-documented lists of species in time and space, appropriate identification of non-native species, and careful records that follow changes in nomenclature, distribution, potential vectors, and ecosystem alterations caused by non-native species.

In terrestrial ecosystems, introduced species are considered the greatest treat to endangered species (Kolar and Lodge 2001) and biodiversity (Lubchenco et al. 1991). We do not have data to make similar statements for marine ecosystems. In the U.S., we spend approximately $130 billion each year to prevent and manage nonindigenous species in terrestrial, freshwater, and marine ecosystems (Pimentel et al. 2000), but very little documentation exists for costs to marine aquaculture, loss of piers to shipworms, or major ecosystem shifts attributed to marine invasions.

Codium fragile ssp. *tomentosoides* at Salem, Massachusetts. Photo credit: P. Erickson

Our knowledge of introduced marine species is from spotty records in time and space of (1) what species are present, (2) how populations have changed over time, (3) the rate and spread of species throughout the region, and (4) changes to the ecosystem. A classic example is the introduction of the Asian green alga or oyster snatcher (*Codium fragile* ssp. *tomentosoides*). It was first reported at Montauk Point, Long Island Sound, New York, in 1957 where it may have been introduced as a fouling organism on ships. *Codium* was introduced in 1961 to the south shore of Massachusetts and reported in 1964 in Boothbay Harbor, Maine, possibly having arrived as small plants on oysters imported for aquaculture (Carlton and Scanlon 1985; Mathieson 2003). By 1972, *Codium* had expanded into the Cape Cod region, where it was abundant probably because of the warm-temperate climate associated with south of the Cape (Fralick and Mathieson 1973; Carlton and Scanlon 1985; Mathieson et al. 2003). Expansion of *Codium* in the Gulf of Maine occurred during the 1970s when fragments of fronds from Boothbay Harbor populations were carried southward by currents, then northward possibly by vessels, shellfish, fragmentation, and motile reproductive cells (Mathieson et al. 2003). Scientific studies focused on its reproduction and fragmentation (Fralick and Mathieson 1972; Prince 1988), buoyancy (Dromgoole 1982), and physiological requirements (Chapman 1999) and provided information on the plant's resilience that was of scientific interest but not directed toward applications to limit its spread. Throughout the history of *Codium's* invasion in the Northeast, management efforts to prevent introductions were virtually non-existent with the exception of policies limiting shellfish importation and associated diseases (J. Fair, pers. comm.) that indirectly prevented or reduced shellfish transfers as a vector of *Codium*.

Introduced species (also referred to as nonindigenous and non-native) occur outside their natural geographic range, reproduce in the wild, and were transported by human intervention (Carlton 2001).

By the 1990s, interest in identifying new introductions, particularly those that may cause harm to humans or ecosystems, spawned efforts to reduce or prevent introductions, establish early detection networks, and develop rapid responses. Documentation of recent invasions of *Codium* in Canada and Australia highlighted ecological impacts and options to manage its spread (Chapman 1999; Trowbridge 1995, 1999). Similarly, the spread of the European green crab (*Carcinus maenas*) on the U.S. West Coast (Cohen et al. 1995; Grosholz et al. 2000; Hunt and Yamada 2003) and the Asian shore crab (*Hemigrapsus sanguineus*) on the East Coast (Lohrer et al. 2000; McDermott 2000; Tyrrell and Harris 2000) have been documented in the literature often along with studies of their impacts on native species and communities.

Managing and controlling populations of introduced species depends on knowing what species are present and identifying potential sources and vectors. Often the arrival of new species is not reported, goes unobserved, or results from serendipitous observations and reporting, especially in marine ecosystems (Carlton et al. 1990; Cohen 2000). Further compounding our assessment of rates of introductions and impacts to ecosystems of non-native species are organisms defined as cryptogenic species, i.e. "a species that is not demonstrably native or introduced" (Carlton 1996). Several approaches are used to survey some or all habitat types or sample a similar habitat over diverse areas (Cohen et al. 1998; Pederson 2001; Hewitt et al. 2004; G. Ruiz, pers. comm.).

Scientists collected species on a floating dock and recorded field notes. Photo credit: G. Lambert

The rapid assessment survey approach relies on taxonomic experts with global experience who are familiar with native and non-native species.

A rapid assessment survey (RAS) approach was used to identify native, introduced, and cryptogenic species present as fouling communities on floating docks and associated structures (ropes, buoys, chains, hulls, and other floating materials) for selected coastal locations along the northeastern U.S. coast from Portland, Maine through New York City and Staten Island, New York. The Northeast RAS was similar to surveys conducted in Puget Sound, Washington, San Francisco Bay, California, and Southern California (Cohen et al. 1998; Cohen et al. 2001; H. Berry pers. comm.; C. Mills pers. comm.) and in Massachusetts and Rhode Island (Cute 2001; Pederson et al. 2001) and relies on taxonomic experts who are familiar with native, introduced, and cryptogenic species for taxonomic identifications.

Reliance on taxonomic experts with global experience is an important component of rapid assessment surveys and one that adds credibility to the long-term records of fouling communities. For all surveys, identification of native, introduced, and cryptogenic species is challenging for several reasons. Many surveys are of short duration, cover limited areas, and identify species to varying degrees of completeness. The northeastern U.S. has a rich history of marine and estuarine species identified by naturalists in the 19th century (Gould 1841, 1870; Verrill, 1874); however, marine traffic and commerce between Europe and the colonies had been ongoing for more than two centuries and date back to Eric the Red and the Basques (Kurlansky 1997; Steneck and Carlton 2001). In the early days of ocean exploration, species were transported in solid ballast and by hull fouling both from the ports of origin and recipient ports (Carlton and Hodder 1995). Larger species are often recorded in naturalist records and recognized as non-native in origin, but smaller species often escape notice. Some of the cryptogenic species identified in the 2000 and 2003 surveys were first identified by Linnaeus in the 18th century. The type specimens may be in Europe or North America, but the origin could be native to the either coast (D. Calder, pers. comm.).

Synidotea laevidorsalis, an isopod that arrived as a hitchhiker on aquaculture shellfish. Photo credit: Southeastern Regional Taxonomic Center, SCDNR

Other challenges to developing comprehensive and accurate lists include misidentifying a species reported for the first time in a locale and assigning it a new name, thus on a global scale creating several names for the same organism. The invasion history of the Asian isopod *Synidotea laevidorsalis* and its regional synonymies illustrates this point. *Synidotea laticauda*, an isopod was identified in San Francisco Bay, where it has an apparently unique distribution and was considered introduced, probably arriving by ship from the western Pacific (Carlton 1979;

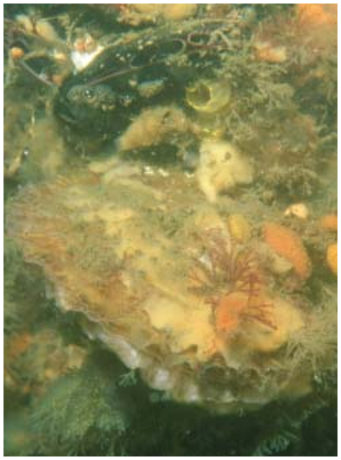
Chapman and Carlton 1991). Based on knowledge of the distribution of native and non-native species, Chapman and Carlton (1991) developed criteria for evaluating the likelihood of a species being introduced to a new region. The ten criteria for evaluating whether new species are likely to be introduced include: (1) the species was previously unknown in the region; (2) range expansion occurred after introduction; (3) potential human-mediated vectors exist; (4) association with other introduced species; (5) association with artificial structures and environments; (6, 7) discontinuous regional and global distribution; (8, 9) passive life history and global mechanisms for dispersion are lacking or insufficient; and (10) exotic evolution origin, i.e., closest relatives are found elsewhere (Chapman and Carlton 1991). Through examination of morphological characteristics used to identify *S. laticauda*, *S. laevidorsalis*, and *S. marplatensis*, and application of the ten criteria for determining if a species was introduced, Chapman and Carlton (1991) determined that *S. laticauda* (San Francisco Bay) and *S. marplatensis* (South America) are junior synonyms for *S. laevidorsalis*. The application of these criteria in determining the likelihood of new species as introduced is widely adopted when reporting new species.

Larry Harris and Robert Bullock shared observations on collected specimens. Photo credit: P. Dyrynda

Taxonomic classifications continue to be updated that may result in confusion for those unaware of these changes. Since the 2000 rapid assessment surveys in Massachusetts and Rhode Island, two species have been given earlier, proper identifications—the introduced red alga *Grateloupia turuturu* (=*G. doryphora*) and the cryptogenic tanaid *Tanais dulongii* (=*T. cavolinii*). For some species, differences of opinion on classifications remain. It is anticipated that genetic studies will resolve the controversy of the compound tunicate *Didemnum* sp. found on the East and West Coasts of the U.S., New Zealand, and elsewhere. The genus is particularly difficult to differentiate based solely on morphological characteristics. Molecular techniques, such as microsatellite DNA analysis, show promise in assisting with taxonomic identification and species' native ranges, as well as primary and secondary origins of the introduced species (Bagley and Geller 2000). Navigating through the species taxonomy requires patience, persistence, and knowledgeable people. Prematurely publishing a taxonomic name before reaching consensus among scientists adds to the confusion (Kott 2002, 2004). Why is it so important to have correct names for species? Without this depth of taxonomic knowledge, it is easy to miss new species and to understate observed changes in ecosystems that may be related to non-native species.

Didemnum sp., a fast-growing sea squirt found on the East and West Coasts of the U.S. Photo credit: L. Harris

Many vectors transport organisms and inoculate new areas. Shipping and hull fouling,



A living *Ostrea edulis* (wavy shell edge is showing) covered with "hitchhikers." Photo credit: P. Erickson

Maria-Pia Miglietta examined a sample of hydroids (small animals related to anemones). Photo credit: P. Dyrynda

aquaculture, marine recreational activities, commercial and recreational fishing, and ornamental trades are some of the more important vectors; but canals, drilling, hull cleaning activities, restoration, research, and floating marine debris may also facilitate transfer of organisms. Invasions have made fundamental changes to ecosystems, altered our coastal communities, and changed the distribution of plants and animals. Some introductions have been deliberate, e.g. shellfish and algae were imported for aquaculture, but the hitchhikers associated with the aquaculture species were not intended to be cultured and sometimes have unwanted consequences for the ecosystem and the aquaculture venture. For example hitchhikers may cause disease, e.g., *Haplosporidium nelsoni* or MSX oyster disease (Carlton 2003) or introduce a predator, e.g., *Urosalpinx cinerea* to Essex, England as a hitchhiker on American oysters (Hayward and Ryland 1990). On a recent survey in southern England, enumeration of hitchhikers on two *Ostrea edulis* shells resulted in 17 species being identified on one shell and 27 on the other (J. Carlton, unpubl. data). Frequently, a suite of introduced organisms is associated with the location of aquaculture introductions (Cohen and Carlton 1995). In San Francisco Bay, three species of bivalve, one gastropod, and one polychaete worm were associated with oyster introductions from the East Coast (Cohen and Carlton 1995).

Once organisms arrive and become established they may be aided in their spread along the coast by secondary vectors. For example, shipping and ballast are significant vectors, but the presence of species in ports and marinas suggests that other vectors, such as hull fouling and sea chests of recreational and fishing vessels, are a source of new inoculations to areas without commercial shipping activities (Wasson et al. 2001; Coutts et al. 2003; Minchin and Gollasch 2003). In addition, artificial structures such as floating pontoons and pilings, bridge and road foundations, and other human structures provide hard substrata habitats in soft bottom areas that may serve as stepping stones to new regions (Connell 2000; Glasby 2001).

RAPID ASSESSMENT METHODS AND PROTOCOLS

Sampling Sites

Sampling locations were chosen within eight National Estuary Programs in the

Northeast from Maine to New York City. The eight estuary programs were: Casco Bay Estuary Program (CBEP); New Hampshire Estuaries Program (NHEP); Massachusetts Bays Program (MBP); Buzzards Bay Project (BBP); Narragansett Bay Estuary Project (NBEP); Long Island Sound Study (LISS); Peconic Estuary Program (PEP); and New York/New Jersey Estuary Program (NY/NJEP). Fouling communities were sampled on floating docks and pontoons that were permanently installed, the floats of which were always underwater irrespective of the tidal cycle. The docks and associated subtidal structures (ropes, wires, buoys, floats, and tires) were located in harbors, ports and marinas and were not removed or cleaned within the past year. For the Northeast surveys, locations were chosen that were presumed to be marine and relatively unaffected by rivers, storm water runoff, and other fresh water sources (Figure 1). Historical uses and other human related activities were identified for each location and weighed heavily in the decision to use a location (Table 1).

Table 1. Locations of sampling sites from north to south and potential vectors of introduction for each site; (H, historical data on introductions; S, shipping and related activities; TS, tall ship and large vessel berthing; MT, marinas and marine trades; A/S, aquaculture and live seafood activities nearby; F/P, freshwater sources and power plants; R, research facilities; and WW, wastewater discharges). See Appendix I for details about each location.

Location	H	S	TS	MT	A/S	F/P	R	WW
Brewer South Freeport, Maine	x	x		x	x			x
Portland Yacht Services, Maine	x	x	x	x	x			x
Port Harbor Marine, Maine	x	x	x	x	x			x
Coast Guard Pier, New Hampshire		x		x	x		x	
Hampton State Pier, New Hampshire		x		x				
Hawthorne Marina, Massachusetts	x	x	x	x		x		x
Rowes Wharf, Massachusetts	x	x	x					
MA Maritime Academy, Massachusetts	x	x						
Coast Guard Station, Massachusetts	x	x		x				
Tripps Marina, Massachusetts				x	x			
Allens Harbor, Rhode Island		x		x	x			
Newport Shipyard, Rhode Island		x	x	x				
Brewer Yacht Yard, Connecticut		x		x				
Milford Yacht Club, Connecticut		x						
Brewer Yacht Haven Marine, Connecticut		x	x	x	x	x	x	x
East Creek Marina, New York				x				
Stirling Harbor Shipyard, New York				x				
South Street Seaport, New York		x	x	x	x	x	x	x
Great Kills Park, New York				x				x
Snug Harbor Cultural Center, New York		x	x	x				x

Other factors also considered were: adequate access for a crew of 12-15 individuals, proximity to laboratory facilities, and appropriate distribution along the length of shoreline to be examined (Appendix I). Although it was intended to select three locations within each NEP, this was not always possible. A total of

Fouling communities were sampled on floating docks and pontoons that were permanently installed, the floats of which were always underwater irrespective of the tidal cycle. Docks and associated subtidal structures (ropes, wires, buoys, floats, and tires) were located in harbors, ports and marinas and were not removed or cleaned within the past year.

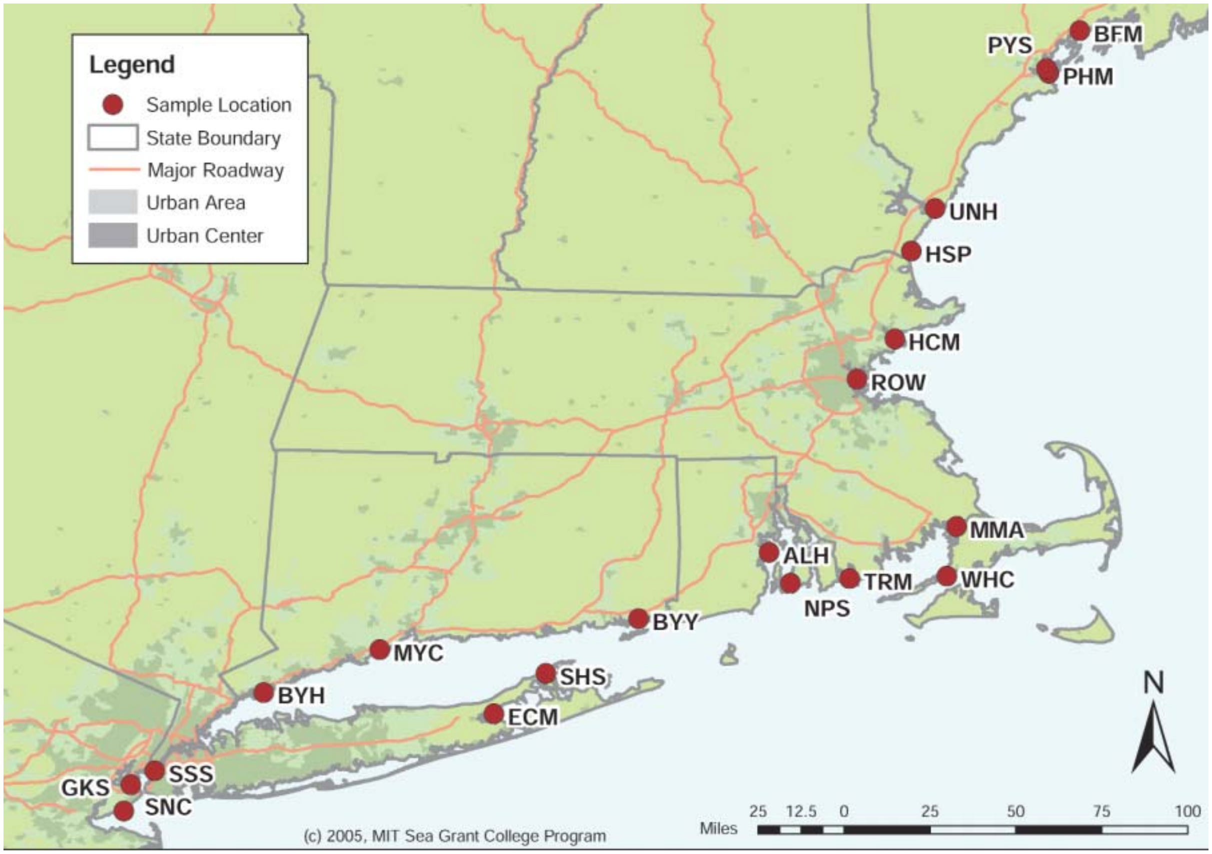


Figure 1. Rapid Assessment Survey sites. ALH=Allen Harbor; BFM=Brewer South Freeport Maine; BYH=Brewer Yacht Haven Marina; BYY=Brewer Yacht Yard at Mystic; ECM=East Creek Marina; GKS=Great Kills Park; HCM=Hawthorne Cove Marina; HSP=Hampton State Pier; MMA=Massachusetts Maritime Academy; MYC=Milford Yacht Club; NPS=Newport Shipyard; PHM=Port Harbor Marine; PYS=Portland Yacht Services; ROW=Rowes Wharf; SHS=Stirling Harbor Shipyard; SNC=Snug Harbor Cultural Center; SSS=South Street Seaport; TRM=Tripps Marina; UNH=UNH Coastal Marine Lab/Coast Guard Pier; WHC=Woods Hole Coast Guard Station.

twenty locations were chosen and distributed as follows: CCEP (3); NHEP (2); MBP (2); BBP (3); LISS (3); PEP (2); NY/NJEP (3).

For all locations, permission from public and private facilities was obtained in advance.

In addition, licenses and permits as required by state and federal agencies for collecting and transporting organisms were obtained to comply with regulations in advance of the survey.

General Approach

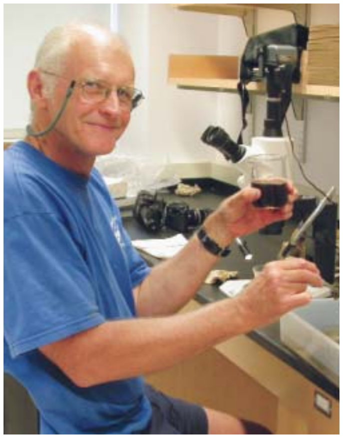
Because verification of species identifications was completed on live specimens the day of collection, laboratory facilities were essential. Arrangements were made in advance at facilities central to the sampling locations. Disposal of specimens was done in accordance with procedures for handling biological materials and consistent with the laboratory procedures. Thus, no organisms were held in running sea water tanks that could empty into nearby waters and all organisms, waste chemicals, and other materials were disposed of according to local, state, and federal guidelines and regulations.

The team participating in the rapid assessment surveys included taxonomic experts familiar with native and non-native marine organisms, students, and a support team to manage logistics (Appendix II). All participants were expected to (1) commit to the weeklong survey; (2) identify species in the field and verify them in the laboratory; (3) maintain a list of species identified and verified; (4) preserve and archive voucher specimens; and (5) provide identification of species from each location at the end of the survey. Voucher specimens could be retained by the investigators or archived along with community vouchers. Some organisms were not identified to species until after the survey. Once the data were recorded, each investigator was asked to review the lists and revise, as appropriate.

The Rapid Assessment Survey in the Northeast was scheduled for mid- to late summer in August when most marine organisms were expected to be at their peak in terms of body mass and, therefore, most easily detected and identified. Two previous surveys in Massachusetts and Rhode Island were also conducted in early August (August 7-11, 2000 and August 14-16, 2000 respectively), facilitating comparison of information. Rapid assessment surveys are limited in time and space, thus some species will be missed or difficult to identify because they thrive at different seasons. For example, several hydroids are abundant and easily identified during spring or early summer and thus were not classified to species because characteristics such as reproductive structures were not present during August (D. Calder, pers. comm.).

Even at low tide, organisms growing on floats are underwater, providing consistency from location to location. Photo credit: G. Lambert

Environmental variables such as dissolved oxygen, temperature and salinity of the water were recorded and measured by Megan Tyrrell. Photo credit: P. Dyrynda


Larry Harris verified classification of live specimens from the day's collections. Photo credit: G. Lambert


Studying larvae and internal structures of tunicates (sea squirts) required Gretchen Lambert's concentration. Photo credit: J. Pederson

At each location, sampling time was limited to one hour and usually three sites were sampled in a day. Species identified in the field were recorded by the dock manager who was in charge of basic data entry at each sampling location. The dock manager was also responsible for recording water quality data at each site using a data sonde for temperature, salinity, and dissolved oxygen. Secchi disk measurements and maximum depth were also recorded. A GPS reading was taken to record spatial location. A community voucher sample for each location and individual voucher samples were collected for identification in the laboratory and for archiving, as appropriate. Bagged, labeled material from each location was stored in coolers with ice until examined in the laboratory.

Equipment

Basic field equipment consisted of leak proof plastic bags, scrapers, nets, coolers with fresh ice packs or ice daily, refractometers, GPS units, dissolved oxygen meters, temperature probes, a Secchi disk, various pans for viewing organisms on the dock, some dissecting equipment (Appendix III), and field sheets. The host laboratory provided basic equipment such as dissecting and compound microscopes and general amenities of lab space. Field guides, taxonomic keys, and other books or monographs were provided by the organizing team for general use and supplemented by individual collections. In addition, solvents, jars, labels, and specialized fixatives were provided by the RAS or individual scientists.

Data Collection

Each participant was expected to record species identified for each sampling location along with any notations. The notes were collected at the end of the survey so that the organizers would have a complete set and these were copied and returned to the investigator. When possible, data were entered into a master list each night and after the completion of the survey were sent to investigators for verification, revision, and insertion of additional species that may have been identified after the survey was completed.

Data entered into a Microsoft Access database could be queried for specific data and relationships. In addition, the data were incorporated into an interactive Geographic Information System (GIS) program and displayed on the web (see http://massbay.mit.edu/invasivespecies/index.html).

RESULTS AND DISCUSSION

Species Distributions

Twenty locations were sampled from Maine through New York City and Staten Island over the course of seven days (Table 1). Although some species are still being verified by taxonomists, approximately 349 protists (microbes, protozoa, and small algae), macro-algal, higher plant, and macro-invertebrate species were identified. Plants as a group had the greatest number of species (98), and echinoderms (four) and sponges (seven) had the least number (although sponges were not always identified to species and may be underrepresented in this survey).

Twenty-nine taxa were identified as introduced species (Table 2) and 32 were identified as cryptogenic (Table 3). Although investigators may use additional classifications in their studies, we restrict our classifications to native, introduced, and cryptogenic species (Carlton 1996). Classifications were based on a list of marine and brackish water introduced and cryptogenic species for the Northeast (Carlton 2003) and the knowledge of participating scientists. Some species were also sent to other specialists for verification.

Carlton (2003) documented 153 introduced and cryptogenic species from Nova Scotia to Long Island Sound (excluding four with uncertain establishment), of which 86 are introduced and 67 are cryptogenic. The number of introduced and cryptogenic species reported in this survey represent 34% and 38% respectively of the known total introduced and cryptogenic species (Carlton 2003). The lower number of species in the 2003 RAS compared to Carlton's (2003) report is related to differences in the total number of taxa included and diversity of habitats covered in the two studies. The 2003 RAS does not include several taxonomic groups that are in the Carlton (2003) report, for example, viruses, bacteria, most protists,

Ship hulls, especially if they travel between distant ports, are a vector for new species introductions. Photo credit: P. Dyrynda

Table 2. List of introduced species identified during the 2003 Rapid Assessment Survey within each National Estuary Program. The abbreviations are: CBEP = Casco Bay Estuary Program, Maine; NHEP = New Hampshire Estuary Program; MBP = Massachusetts Bays Program; BBP = Buzzards Bay Program (for this report includes the Woods Hole Coast Guard location); NBEP = Narragansett Bay Estuary Program; LISS= Long Island Sound Study; PEP= Peconic Estuary Program; NY/NJ Estuary Program. State and number of sampling sites within each estuary program are given.

Taxonomic Species	**CBEP ME-3**	**NHEP NH-2**	**MBP MA-2**	**BBP MA-3**	**NBEP RI-2**	**LISS CT-3**	**PEP NY-2**	**NY/NJ EP-3**
Chlorophyceae								
Codium fragile ssp. *tomentosoides*				x	x	x	x	
Rhodophyceae								
Grateloupia turuturu					x			
Lomentaria orcadensis		x						
Neosiphonia harveyi	x	x	x	x	x	x	x	x
Porifera								
Halichondria bowerbanki	x	x	x	x	x	x	x	x
Cnidaria								
Cordylophora caspia							x	
Diadumene lineata	x		x	x	x	x	x	x
Sagartia elegans			x					
Polychaeta								
Janua pagenstecheri			x	x				
Mollusca: Gastropoda								
Littorina littorea				x				
Mollusca: Bivalvia								
Ostrea edulis			x					
Arthropoda: Isopoda								
Ianiropsis sp.				x	x	x		
Synidotea laevidorsalis								x
Arthropoda: Amphipoda								
Caprella mutica	x		x	x	x	x		
Microdeutopus gryllotalpa				x		x		
Arthropoda: Decapoda								
Carcinus maenas	x	x	x	x	x	x	x	x
Hemigrapsus sanguineus		x	x	x	x	x		x
Arthropoda: Insecta								
Anisolabis maritime	x							
Entoprocta								
Barentsia benedini						x		x
Bryozoa								
Alcyonidium sp.	x	x			x	x		x
Bugula neritina	x		x		x			
Membranipora membranacea	x	x	x		x			
Urochordata: Tunicata								
Ascidiella aspersa	x		x	x	x			
Botrylloides violaceus	x	x	x	x	x	x	x	x
Botryllus schlosseri	x	x	x	x	x	x	x	x
Didemnum sp.		x	x	x	x			
Diplosoma listerianum	x		x	x				
Styela canopus				x		x		x
Styela clava	x	x	x	x	x	x	x	

Sagartia elegans, a small anemone seen here growing on a mussel, was found at only one location in the 2000 and 2003 surveys. Photo credit: P. Dyrynda

Taxonomic Species	CBEP ME-3	NHEP NH-2	MBP MA-2	BBP MA-3	NBEP RI-2	LISS CT-3	PEP NY-2	NY/NJ EP-3
Protista								
Foraminifera sp.	x	x						
Porifera								
Leucosolenia sp.	x	x	x	x	x	x	x	
Scypha sp.			x	x	x	x		
Cnidaria								
Campanularia sp.	x	x				x		
Clytia hemisphaerica		x						
Dynamena pumila		x						
Ectopleura larynx	x	x	x					x
Laomedea calceolifera	x			x		x		
Obelia bidentata						x		x
Obelia dichotoma		x	x	x	x	x	x	
Obelia geniculata	x		x		x			
Obelia longissima	x		x	x	x	x		x
Opercularella lacerata		x						
Pennaria disticha				x				
Polychaeta								
Harmothoe imbricata	x	x	x	x	x	x		x
Lepidonotus squamatus	x	x	x	x	x	x	x	x
Mollusca: Gastropoda								
Tenellia adspersa								x
Cuthona gymnota	x	x	x					
Arthropoda: Tanaidacea								
Tanais duglongii					x			
Arthropoda: Amphipoda								
Jaera marina		x						
Bryozoa								
Amathia vidovici				x				
Bowerbankia gracilis	x	x	x	x	x	x		x
Bowerbankia imbricata					x	x	x	x
Bugula simplex			x			x		
Bugula stolonifera	x		x	x	x	x	x	
Cryptosula pallasiana	x		x	x	x	x	x	
Electra pilosa	x	x	x		x	x		x
Walkeria uva				x				
Urochordata: Tunicata								
Ciona intestinalis	x	x	x	x	x	x		
Molgula citrina	x	x	x					
Molgula manhattensis			x	x	x	x	x	x
Molgula provisionalis	x	x						

Table 3. List of cryptogenic species identified during the 2003 Rapid Assessment Survey within each National Estuary Program. See Table 2 for abbreviation descriptions; number refers to the number of sampling locations in each estuary program.

The orange sheath tunicate (*Botrylloides violaceus*) grew on kelp (*Laminaria* sp.) holdfasts and over another introduced tunicate, the pinkish, partially exposed oval shape of *Ascidiella aspersus*. Photo credit: anonymous

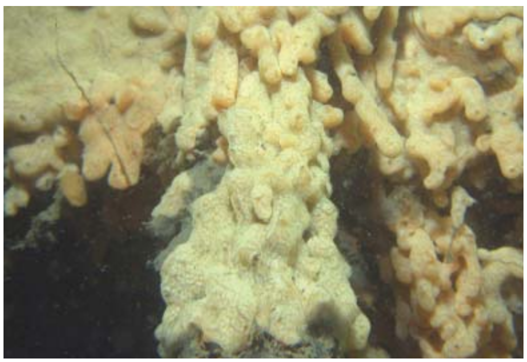
Two compound tunicates, *Botryllus schlosseri*, the golden star tunicate, and *Botrylloides violaceus*, the orange sheath tunicate, competed for space. Photo credit: P Erickson

fish, birds, as well as species found in soft bottom, marsh, and brackish water habitats, unless species were macroscopically visible (specifically some protists and bacteria form visible mats). In addition, the habitat in the 2003 RAS was limited to marine floating docks and related structures, while fixed artificial structures (seawalls, pilings, etc.), the water column, natural hard substrata, marshes, and sand and mud habitats were included in the Carlton (2003) report; RAS habitat limited the number of species observed and reported.

Locations

The lists of introduced and cryptogenic species in Tables 2 and 3 do not distinguish species found on floats from those that may have been found on floating objects or on ropes, wire, and hoses attached to pontoons that extended into deeper waters, possibly beneath a pycnocline. Species observed on stationary piers, sea walls, rocky shores and other nearby habitats were not included.

The only new species identified in this region was the Asian isopod (*Synidotea laevidorsalis*) that was found at the South Street Seaport, New York location. This species appears to have arrived with oyster aquaculture and possibly by shipping and has been migrating northward (Carlton, unpubl. obs.). The distribution of an anthozoan (*Sagartia elegans*) was observed at the Salem, Massachusetts site, where it was originally identified in the 2000 survey. The red alga (*Grateloupia turuturu*) appears to be spreading from its original location near Roger Williams College, Rhode Island, and in 2004 it was also reported in Long Island Sound. The growth of *G. turuturu* may be three feet or more in length and the alga has the potential to shade and alter communities where it is found (Villalard-Bohnsack and Harlin 1997; Villalard-Bohnsack 2002).



The compound sea squirt *Didemnum* sp. is found in subtidal areas throughout New England from Connecticut to New Hampshire, as well as in Georges Bank. Photo credit: L. Harris

Tunicates, as a group, appear to be successful invaders based on the number of introduced and cryptogenic species (11 in this study) relative to the number of native species present (two in this study). Four introduced compound ascidians (*Botryllus schlosseri*, *Botrylloides violaceus*, *Diplosoma listerianum*, and *Didemnum* sp.) were abundant and overgrew algae and fouling community species. Other tunicate species that were locally abundant included several introduced (*Styela clava*, *Ascidiella aspersa*) and cryptogenic (*Molgula manhattensis*, *M. citrina*, *M. provisionalis*, and *Ciona intestinalis*) solitary tunicates.

One of the most aggressive species observed is the compound ascidian *Didemnum* sp. that was identified at four locations in Massachusetts (Cape Cod Canal and Buzzards Bay) and at five sites throughout Narragansett Bay in the 2000 RAS (Pederson et al. 2001). In the present survey, *Didemnum* sp. was found at six locations from New Hampshire to Connecticut. *Didemnum* sp. was collected in Fort Island Narrows, Damariscotta River, Maine in 1993 (identified by G. Lambert in 2004; voucher specimen at Darling Marine Lab) and was anecdotally reported in Maine as early as 1988 (Valentine 2005). The taxonomic nomenclature is not resolved for this species and a species name has not been assigned.

Membranipora membranacea are the round, tan to white, flat bryozoan colonies that grew on this kelp blade along with the orange sheath tunicate, *Botrylloides violaceus*. Photo credit: P. Dyrynda

Where it is observed on near-shore hard substrata, *Didemnum* sp. is a fast growing invader covering large areas and overgrowing other sessile organisms. It has been found in numerous locations throughout the Northeast and U.S. West Coast (G. Lambert, unpublished observations; Valentine 2005). It was reported growing on cobble substrata offshore on Georges Bank, one of the first observations in the Northeast of an introduced species near the shelf break of the continental shelf (Valentine 2005). Surveys of Georges Bank documented *Didemnum* sp. covering about 70% of 70 km^2 cobble area (Bullard et al. submitted). The presence of this species on Georges Bank raises concerns about its impact on the highly productive shellfish beds and groundfish habitat. *Didemnum* sp. is described as pancake batter that appears to flow over substrata where it overgrows most species. It may profoundly alter communities by outcompeting sessile native species for space, reducing availability of food sources or refuges for juvenile groundfish and scallops, and preventing settlement of benthic organisms.

The highly aggressive sea squirt *Didemnum* sp. grew over another introduced sea squirt, the solitary tunicate *Styela clava*. Photo credit: G. Lambert

Another species that was conspicuous is the bryozoan *Membranipora membranacea*, which may cover much or all of kelp blades (*Laminaria* sp.). It was first observed at the Isle of Shoals (Berman et al. 1992) and has spread throughout the Gulf of Maine. In this survey it was reported from South Freeport, Maine, to Newport, Rhode Island. Recent studies suggest that it can grow on green alga (*Codium fragile* ssp. *tomentosoides*), the terete brown alge (*Desmarestia aculenta*) and flattened brown algae (*Agarum clathratum*, *Fucus distichus* ssp. *evanescens*, and

The Asian shore crab (*Hemigrapsus sanguineus*) has spread from the Cape May/Delaware region, where it was first reported in 1988, north to Maine and south to North Carolina. Photo credit: P. Dyrynda

The cryptogenic sea squirt species, *Molgula manhattensis*, is a frequent fouling organism on boats, marina floats and ropes during late summer and early fall. Photo credit: G. Lambert

Saccorhiza dermatodea), thereby extending its habitat range to new depths and possibly extending its range geographically (Harris and Mathieson 2000). West Coast kelp (*Macrocystis pyrifera*) heavily fouled with *M. membranacea* can lose up to one-third of its blades compared to unfouled plants (Dixon et al. 1981), suggesting there may be similar impacts on East Coast laminariales.

Three introduced species—the periwinkle snail (*Littorina littorea*), European green crab (*Carcinus maenas*), and green alga (*C. fragile* ssp. *tomentosoides*)— have been in the region for nearly 50 years or longer. Much of what we know about these species' impacts to the community is based upon studies conducted after their arrival. Two of these species (*L. littorea* and *C. maenas*) are considered ecological engineers as herbivores and predators, respectively (Menge 1976). *Codium fragile* ssp. *tomentosoides* forms monocultures in subtidal areas and displaces eelgrass or *Zostera marina* (Garbary et al. 2004) in locations where it could attach to hard surfaces (e.g. shells, rocks, bivalves). In 2003 and 2004 it washed ashore on the beaches of Harwichport, Massachusetts, and created a nuisance by reaching heights of three feet or more and decaying with a noxious odor. *Styela clava* and other non-native ascidians can also profoundly affect the composition of a community similar to the situation in Chile with the introduced *Pyura praeputialis* (Castilla et al. 2004).

The recent introduction of the Asian shore crab (*Hemigrapsus sanguineus*) to the Cape May, New Jersey, and Delaware region and its subsequent spread northward to Maine and south to North Carolina has provided an opportunity to assess changes at several locations (Lohrer et al. 2000; McDermott 2000). Comparisons were made with diet and niche of *H. sanguineus* in its native range and in comparable habitats in Long Island Sound (Lohrer et al. 2000). Another study examined the relationship between *H. sanguineus* and other crustaceans, especially *C. maenas* in Massachusetts, New Hampshire and Maine (Tyrrell and Harris 2000). This research includes a location that was surveyed prior to the arrival of *H. sanguineus* (Tyrrell and Harris 2000) and that continues to be monitored (M. Tyrrell, unpubl. data).

Five introduced (*Neosiphonia harveyi*, *Halichondria bowerbanki*, *C. maenas*, *B. violaceus*, and *B. schlosseri*) and one cryptogenic (*Lepidonotus squamatus*) species were reported in all estuary program locations (Tables 2 and 3). Three introduced (*Diadumene lineata*, *H. sanguineus*, and *Styela clava*) and two cryptogenic (*Leucosolenia* sp. and *Harmothoe imbricata*) species were found in all but one location. However, the lack of species in a particular location does not necessarily

Table 4. Number of species by taxonomic group for each state or region.

Taxonomic Group	ME	NH	MBP	SoMA	RI	CT	PEC	NYC	Total
Number of sites	3	2	2	3	2	3	2	3	20
Plants	39	39	22	47	26	25	26	23	98
Porifera	5	5	6	6	6	6	2	4	7
Cnidaria/Ctenophores	15	11	11	11	10	8	7	12	35
Platyhelminths/Nemertines	14	10	4	11	17	13	15	13	54
Polychaetes	12	7	9	13	12	9	7	8	21
Molluscs	13	13	7	14	9	11	5	9	32
Crustaceans	19	22	16	26	23	27	13	18	56
Bryozoans	13	6	7	12	13	16	8	8	27
Echinoderms	4	5	0	0	1	1	0	0	6
Tunicates	9	7	8	10	7	7	5	3	13
TOTAL	143	125	90	150	124	123	88	98	349

mean that it is not found within the estuary or state. For some species, their absence from floating docks may reflect that pontoons are poor habitats for the species or the salinity was too low at that site. For example, *L. littorea* and *Ostrea edulis* have a much broader range of distribution than reported here and are abundant in nearby habitats. Two species were found in only one location, *S. elegans* (at the same location where it was first identified in 2000) and *S. laevidorsalis* (a new introduction to the New York City region).

The total number of species identified in this survey at each National Estuary Program (some listed by state) ranges from 88 to 150 (Table 4), reflecting in part differences in the number of sampling locations (two or three) as well as environmental differences (e.g. temperature, salinity, currents) and other characteristics (pontoon surfaces and local differences in use of the region). The greatest numbers of introduced species were recorded from marinas in Massachusetts and Rhode Island (Figure 2). Introduced tunicates

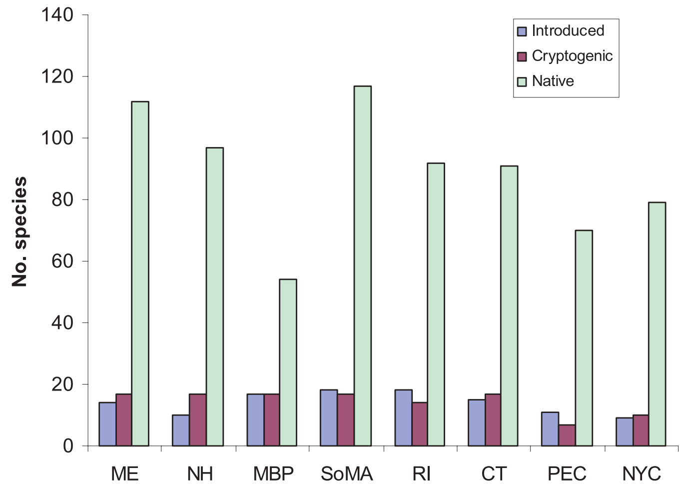


Figure 2. Number of introduced, cryptogenic and native species found within each National Estuary Program listed by program or state.

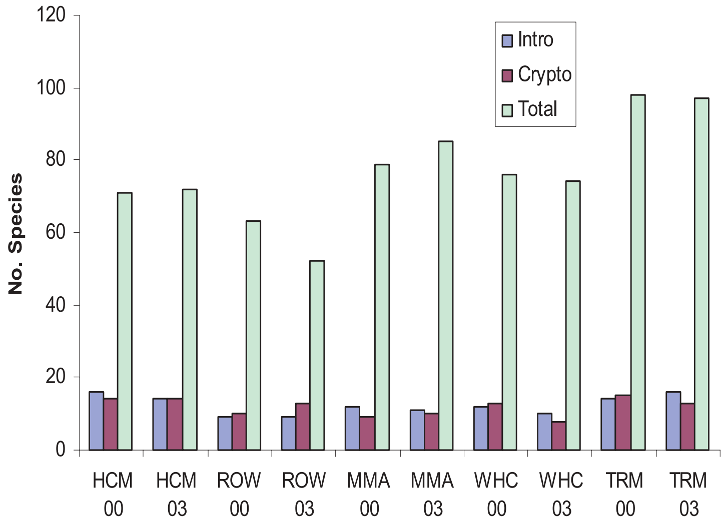


Figure 3. Comparison of number of introduced, cryptogenic and total species (includes introduced and cryptogenic) found at five Massachusetts locations sampled in both 2000 and 2003.

represented 25% of the total number of introduced species, whereas tunicates represented only 4% of the total number of species. In addition to number of species, biomass was a significant factor. Although biomass is difficult if not impossible to measure, it may be of greater significance. For example, introduced ascidians formed a significant percentage of the total biomass at many locations. Often one species constituted the majority of the biomass at the site, e.g. *Molgula manhattensis* or *Ascidiella aspersa*.

Because all five locations in Massachusetts were previously sampled in August 2000, data from the two years were compared. The number of species recorded at each site and paired for each year was similar (Figure 3). Fewer total species were recorded at Rowes Wharf in 2000 than in 2003 and six more species were recorded at Massachusetts Maritime College in 2003 than in 2000. However, there were differences in the introduced and cryptogenic species recorded between the two survey years (2000 and 2003) for any given location, with more disparity between cryptogenic species than introduced. Introduced species observed from the 2000 RAS compared to the 2003 RAS differed in species that use floats as marginal habitats, e.g. *L. littorea* (recorded at one of the five Massachusetts locations in 2003) and *H. sanguineus*, (recorded at four locations of the five in 2003), which if they become dislodged are unlikely to return. In addition, a small red alga (*Bonnemaisonia hamifera*) and a mysid shrimp (*Praunus flexuosus*) were not recorded in the 2003 RAS. Cryptogenic species that were not recorded in both 2000 and 2003, but observed in one or the other years were small hydroids (five); small motile crustaceans (three) and a bryozoan.

The question of how this study compares to other similar studies is frequently asked, but such comparison between surveys are complicated for a number of reasons. Many of the literature reports of introduced and cryptogenic species are compilations from all habitats, combine brackish and marine species, use different methods and approaches, and for all surveys different taxonomists. Nonetheless, there are fewer introduced (and native) species reported for this survey than are reported for California, especially San Francisco Bay, and Puget Sound (Cohen 2000). Chapman (2000) observed that west coasts of the Pacific and Atlantic oceans have greater numbers of introduced and native peracaridan (amphipod and isopod) species compared to the east coasts of the Pacific and Atlantic oceans. A comparison of temperature and other environmental factors suggested that geography limits species invasions (Chapman 2000). The wide continental shelf off the U.S. east coast is also considered a significant factor in there being fewer species on the Atlantic than the Pacific side (Chapman 2000). A recent rapid assessment survey of floating docks in southern England reported over twice as many tunicate species as recorded in the present survey and generally supports Chapman's (2000) hypothesis for ascidians. However, temperature and physiological tolerance alone do not predict introduced species success in becoming established (C. Hewitt, pers. comm.) making it difficult to develop models and predictions of what species are likely to invade what regions. Given the diversity of methodologies used to record and report marine introductions, data from different locations may not be easily compared.

Ballast water, hull fouling, and other shipping vectors are significant sources of new introductions. Our primary trading routes are with Europe and it is not surprising that most of the introduced species in the northeast have come from Europe. A large number of species have also originated in Asia, some of which were probably introduced to the U.S. from Europe where they were first introduced and established. Southern England was and still is a frequent origin of vessels traveling to the Americas. A recent rapid assessment survey in southern England reported native and non-native species for the ten locations visited. Nine of the introduced species in this survey were found in the southern England survey (unpubl. data). Because of the long history of maritime transport between southern England and the northeastern U.S., many species will be found on both sides of the Atlantic, but may not be identified as introduced or cryptogenic (unpubl. data). There are other vectors that may have introduced organisms. Shellfish and aquaculture introductions were formerly very important vectors and may have been the source of many of our introduced or cryptogenic species that arrived several or many decades ago. Today, the internet and shipping by air makes it possible to purchase and send or receive organisms from anywhere in the world.

Interspersed with an introduced orange sponge (*Halichondria bowerbanki*) are the sea squirts, *Molgula manhattensis* (tan colored solitary tunicate), *Botryllus schlosseri* (star tunicate), and *Botrylloides violaceus* (reddish, orange sheath tunicate). Photo credit: G. Lambert

The large solitary sea squirts (*Styela clava*) are covered by a rough tunic often attaching to ropes dangling in the water. Photo credit: P. Erickson

A floating dock from Portland Yacht Services with its bottom surrounded by a geotextile fabric to contain mobile organisms was hoisted to the shore for scientists to examine. Photo credit: G. Lambert

A view of Boston Harbor from Rowes Wharf. Photo credit: P. Dyrynda

Environmental Data

The Cape Cod region is an area of transition between the Virginian and Boreal Biogeographical provinces, although many species are found throughout the two provinces. For the sampling week, the average surface temperature north of Cape Cod (north of Bourne,

Table 5. Surface and maximum depth temperatures, salinity, and dissolved oxygen at locations, nd = no data.

Locations	**Surf Depth (m)**	**Max Depth (m)**	**Secchi Depth (m)**	**Surf Temp (°C)**	**Max Temp (°C)**	**Surf Sal (psu)**	**Max Sal (psu)**	**Surf (m/L)**	**Max (mg/L)**
Freeport, ME (BFM)	0.1	3.5	nd	17.3	16.7	31.6	31.6	5.7	5.4
Portland, ME (PHM)	0.1	2.0	2	15.7	14.1	30.4	31.2	6.2	4.7
So. Portland, ME (PYS)	0.1	4.5	2.3	15.4	14.4	30.5	31.2	7.5	4.9
Portsmouth, NH (UNH)	0.1	2.0	2	14.3	14.2	31.4	31.6	7.3	6.6
Salisbury, NH (HSP)	0.1	3.0	2.9	16.4	15.9	29.8	27	6.0	6.4
Salem, MA (HCM)	0.1	3.75	3.5	20.8	15.6	31.5	31.9	6.1	6.8
Boston, MA (ROW)	0.1	4.0	3.5	19	15.2	25	nd	6.2	6.8
Bourne, MA (MMA)	0.1	4.5	2.5	22.9	22.8	31.5	31.5	6.3	5.8
Woods Hole, MA (WHC)	0.1	4.75	3	24	22.5	31.6	32.1	4.8	0.7
Westport, MA (TRM)	0.1	2.5	1.9	24.5	24.4	32.0	32.0	6.2	6.0
No. Kingston, RI (ALH)	0.1	1.75	1.3	23.7	23.6	27.8	29.0	6.0	4.0
Newport, RI (NPS)	0.1	6.8	2.5	21.2	19.5	31.3	31.7	6.4	4.7
Mystic, CT (BYY)	0.1	2.5	~2	23.7	22.0	27.0	27.9	5.1	0.5
Milford, CT (MYC)	0.1	4	nd	23.6	23.9	7.8-17.6	26.9	6.0	2.8
Stamford, CT (BYH)	0.1	3	murky	22.4	21.7	23.5	26.6	4.0	2.6
So. Jamesport, NY (ECM)	0.1	2.0	1	26.5	26.3	22.7	27.3	6.0	4.0
Greenport, NY (SHS)	0.1	2.0	1.8	26.1	25.2	28.1	28.8	4.8	2.8
New York, NY (SSS)	nd	nd	nd	nd	nd	25	nd	3.1	nd
Staten Island, NY (GKS)	0.1	nd	nd	25.5	25.4	14.8	nd	3.1	1.7
Staten Island, NY (SNC)	0.1	nd	nd	24.3	23.8	27	nd	4.2	4.1

Massachusetts and Woods Hole, Massachusetts) was 17.0 ^{o}C (± 0.85), for the three sites on Cape Cod the temperature was 23.8 ^{o}C (± 0.47) and south of Cape Cod the average temperature was 24.1 ^{o}C (± 0.57). Salinity ranged from a low of 7.8 to 17.6 psu at two surface locations at the Milford Yacht Club, Connecticut, to 32 psu at Tripp's Marina, Massachusetts. Even though the salinity at Milford was low relative to the other locations, species that are generally not tolerant of low salinities were found at this site (e.g., the solitary rough sea squirt *S. clava* and the orange sheath sea squirt *B. violaceus*). All ascidians at this location were rare and were from the end of a long rope where the recorded bottom salinity for this site is 27 psu as shown in Table 5. With this as a caveat, we included data from this location in this report.

A measure of the clarity of the waters was reflected in Secchi disk depths. Mean depth (± S.E.) for sampling locations were 2.7 m (± 0.29) north of Cape Cod; 2.5 m (± 0.32) Cape Cod; and 1.4 m (± 0.35) south of Cape Cod. Water clarity was lower in areas of high coastal development near the marina and shallow depths. Temperature, salinity, and water clarity are related to introduced species distributions that would not be reflected in a one week survey.

Rapid assessment surveys have the advantage of providing high-quality data in a short period of time, while incurring minimal expense relative to other survey approaches.

CONCLUDING THOUGHTS

The 2003 rapid assessment survey identified introduced and cryptogenic species in fouling communities of floating dock and piers and associated structures for each of the eight National Estuary Programs (NEPs) in the Northeast. Rapid assessment surveys are relatively quick, cost-effective approaches for generating species lists and may provide reliable baseline data for additional studies.

The results from the study permit comparisons across the estuary programs, but more importantly they inform states and regional groups about species that are present in the area and those that may be spreading. The 2000 surveys in Massachusetts and Rhode Island have stimulated action to prevent, reduce and manage marine invasions in each state. In Massachusetts, an Aquatic Invasive Species Management Plan has been accepted by the governor and actions are being implemented to prevent and manage introductions. A major focus of the activities is to identify a process for early detection of new introductions and generate rapid response approaches to remove or control invasions in both marine and freshwater ecosystems.

Niels Hobbs used a sieve to concentrate small crustaceans such as amphipods, skeleton shrimp, and isopods. Photo credit: P. Dyrynda

Various activities undertaken by the state and federal agencies and the estuary programs, using data from these surveys, speak to their value as a tool for raising awareness and leading toward prevention and management actions that reduce the impact of introduced species.

Rhode Island has used the data from the 2000 Rapid Assessment Survey to support legislation to prevent or minimize introductions from ballast water. Preliminary data from the 2003 Rapid Assessment Survey has supported other efforts to manage invasions. For example, the Casco Bay Estuary Program and partners sponsored a Marine Invasive Species Forum that has resulted in stronger collaborations among agencies and the public within Maine and others in the Gulf of Maine region.

Ideally, field sampling surveys should include all estuarine and marine habitats. Port surveys in Australia sampled artificial and natural hard substrata as well as soft substrata (Hewitt et al. 2004). Sampling methods included diver surveys, core and grab samples, plankton collections, use of seines and benthic sleds, and video and still photography. The field surveys were conducted over six months and required considerably more funding than the weeklong rapid assessment surveys described here. Another approach used to monitor introduced species is the deployment of small plates (e.g. composed of plastic, PVC, Lucite, other artificial materials, wood, or natural substrates) in marinas and follow species settlement over time to measure the rate and abundance of introduced and cryptogenic species. Settling plate surveys may be costly, may have limited surface area for settlement, and may not adequately assess rare or ephemeral species. A drawback for all sampling approaches is the difficulty in identifying juvenile stages, which is particularly challenging on fouling plates if nearby adult species are not included in the samples. A major strong point of rapid assessment surveys is the team of specialists at the same location who quickly alert one another to the presence of species a specialist might have overlooked. This generates a reasonably complete species list for the site in a short period of time.

Rapid assessment surveys, while limited, have the advantage of providing high-quality data in a short period of time, while incurring minimal expense relative to other survey approaches. The various activities undertaken by the state and federal agencies and the estuary programs, using data from these surveys, speak to their value as a tool for raising awareness and leading toward prevention and management actions that reduce the impact of introduced species.

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The bottom of a floating dock with native and non-native species. Photo credit: P. Dyrynda

Codium fragile ssp. *tomentosoides* was recorded at four survey sites. Photo credit: J. Pederson

The introduced species *Diadumene lineata* was sampled in all locations except New Hampshire. Photo credit: R. Buchsbaum

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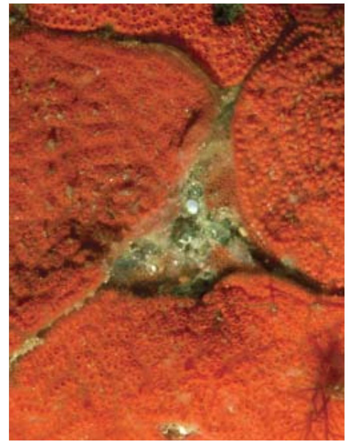

A close view of *Botrylloides violaceus.* Photo credit: P. Erickson

An aquaculture cage from New York Harbor covered with native and non-native fouling organisms. Photo credit: P. Dyrynda

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The Asian green alga (*Codium fragile* ssp. *tomentosoides*) also known as oyster catcher is attached to a native gastropod (*Crepidula fornicata*) and may be washed ashore causing a nuisance to beach goers. Photo credit: anonymous

Personal Communication

H. Berry, University of Washington, Friday Harbor Labs, Seattle, Washington, 2000
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J. Fair, Formerly with the Massachusetts Division of Marine Fisheries, 1977
C. Hewitt, MAF Biosecurity, Wellington, New Zealand, 2004
C. Mills, University of Washington, Friday Harbor Labs, Seattle, Washington, 2000
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M. Tyrell, Wells National Estuarine Research Reserve, Wells, Maine, 2003

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The orange sheath tunicate, *Botrylloides violaceus*, hitchhiking on a native spider crab, *Labinia* sp. Photo credit: P. Dyrynda

A variety of recreational vessels were docked on this rainy day. Photo credit: P. Dyrynda

APPENDIX I

RAPID ASSESSMENT SURVEY 2003 SAMPLING LOCATIONS

Locations within the National Estuary Programs (NEP) in the U.S. Northeast were chosen for establishing a baseline of native and non-native species in fouling communities of floating pontoons. The following NEPs were included in the study: Casco Bay Estuary Program, Maine; Great Bay Estuary Program, New Hampshire; Massachusetts Bays Program, Massachusetts; Buzzard Bay Estuary Program, Massachusetts; Narragansett Bay Estuary Program, Rhode Island; Long Island Sound Estuary Program, Connecticut; Peconic Estuary Program, New York, and New York/New Jersey Estuary Program, New York. Locations were chosen based on several criteria. The focus was on marine harbors, ports, and marinas from southern Maine through New York City within each estuary program that had floating docks remaining in the water throughout the year. Areas were chosen for their proximity to commercial and recreational vessel traffic, historical marine transport, past or present aquaculture activities, and other potential vectors for introductions. In addition, logistical issues, such as capacity, parking, and ease of access by automobiles were also a consideration. The sampling locations are listed below, from north to south, and each listing includes sampling date, time (usually one hour sampling), a brief description of the site and dominant biological fouling communities, and any unusual physical conditions.

Brewer South Freeport Marine (BFM), South Freeport, Maine

August 4, 2003 13:15 PM (http://www.byy.com/South%20Freeport/index.cfm)

A relatively large marina, located on the banks of the Harraseeket River on the edge of Casco Bay, Brewer South Freeport Marine served historically as a ship building port. The marina provides about 140 seasonal moorings and slips with dockside depths of 14 feet. There are several permanent floating docks that were heavily covered with fouling organisms, with a base consisting of *Mytilus* and *Metridium*. *Diadumene lineata* and *Bugula neritina* were present along with massive *Ectopleura* (=*Tubularia*) on outer floats.

Recreational boats may transport organisms within coastal communities. Photo credit: G. Lambert

Scientists captured samples of fouling communities at floating docks. Photo credit: P. Dyrynda

Portland Yacht Services (PYS), Portland, Maine

August 4, 2003 10:48 AM (http://www.portlandyacht.com)

The Portland Yacht Services is located in Casco Bay on Fore Street, just north of downtown Portland near the historic Old Port. It has approximately 150 slips and moorings. Only two floats remain in the water year round, one large and the other small. The owner, Phineas Sprague arranged to have the smaller one (10 ft by 4 ft) hauled out of the water and flipped over at the time we surveyed. A geotextile fabric was placed underneath the Styrofoam float to enclose fish and all swimming organisms. The two floats were covered with green (ulvoids) and brown algae (*Laminaria* sp.), barnacles, *Mytilus* and *Ectopleura*. Portland's oil terminals and shipping ports were well within sight of the site. It rained heavily the day we sampled.

Port Harbor Marine (PHM), South Portland, Maine

August 4, 2003 09:10 AM (http://www.portharbormarine.com)

Port Harbor Marine in Casco Bay is located at Spring Point Drive and was the site of the former South Portland Shipyard that built Liberty Ships during WWII. It has approximately 400 slips and 140 ft of transient dockage, and a large number of permanent Styrofoam floats. Floats were low in the water (hard to reach) and heavily fouled with macrophytes and other organisms. The base on the floats was *Mytilus* with *Laminaria* that was covered with epiphytes. Portland's oil terminals and shipping ports were well within sight of this location. It poured rain the day we sampled.

Two oil platforms in Portland Harbor that are towed from one location to another often are covered with fouling organisms. Photo credit: P. Dyrynda

University of New Hampshire and Coast Guard Pier (UNH), New Castle, New Hampshire

August 3, 2003 08:50 AM (http://marine.unh.edu/facilitiescml.html)

The Coast Guard Station is a permanently operated facility within the Great Bay Estuary near the mouth of the bay and is surrounded by a highly developed shoreline. It is fully marine and near the historic Portsmouth port. Its cement floating docks were well encrusted underneath but required reaching far under the docks to obtain sufficient amounts of material for identification. It is also adjacent to a shore-based University of New Hampshire facility with a pier, floats, and cages. There were large *Mytilus* and many larger macrophytes (e.g. ulvoids and *Laminaria*) and *Ectopleura*. Several large *Metridium* and *Asterias* were also observed.

A native mussel (*Mytilus edulis*) covered with an encrusting cryptogenic bryozoan. Photo credit: P. Dyrynda

Hampton State Pier (HSP), Hampton, New Hampshire

August 3, 2003 10:30 (http://www.nhstateparks.com/piers.html)

This marina is within a state park located near the Seabrook Bridge in Hampton, New Hampshire. It supports commercial and recreational fishing and has floating docks for recreational boating. The area is highly developed and supports tourism. The area is in a tidal estuary with a strong outgoing tide at the time of sampling. The floats were covered with small *Mytilus*, *Ulva*, and extensive clumps of *Ectopleura*. A variety of organisms was present.

Hawthorne Cove Marina (HCM), Salem, Massachusetts

August 3, 2003 13:15 (http://www.marinas.com/hawthronecovemarina)

Located in the Massachusetts Bay Estuary, Hawthorne Cove Marina is within a heavily developed shoreline. It is fully marine, and near the historic Salem port. Several tall ships visited the area in 2000. There are approximately 110 slips and 135 docking areas and the marina accommodates boats up to 65 feet with drafts of 8 ft at MLW. It is located near a power plant and may be under the influence of the thermal plume. The floats were covered with *Mytilus* and *Laminaria* that in turn were covered by colonial tunicates and bryozoans. This is the only location with *Sagartia*.

The introduced yellow orange sponge *Halichondria bowerbanki* surrounded by the cryptogenic sea squirt *Molgula manhattensis*. Photo credit: P. Dyrynda

The Marina at Rowes Wharf (ROW), Boston, Massachusetts

August 5, 2003 09:50 AM (http://www.marinaatroweswharf.com)

Rowes Wharf Marina, which is within Boston Harbor and Massachusetts Bay Estuary, is fully marine, and hosted several tall ships in 2000. It is a highly developed environment with commercial traffic and commuter and cruise vessels nearby. It has approximately 42 slips and can accommodate large vessels. A base of mussel (*Mytilus*) and macrophytes (ulvoids, reds and *Laminaria*) were found on the permanent floating docks. Ctenophores and *Aurelia* were

Scientists collected samples from a floating dock showing various types of vessels that can be found in marinas. Photo credit: P. Dyrynda

observed in the water column; caprellids were very common; *Laminaria* was relatively free of organisms. Several species of large solitary ascidians were particularly abundant at this site.

Massachusetts Maritime Academy (MMA), Bourne, Massachusetts

August 5, 2003 15:33 AM (http://www.mma.mass.edu)

The Maritime Academy is not a public marina, but home to its large training vessel with a draft of 32 ft, docked along one side of the permanent floating dock. There are also seasonal floating docks for smaller vessels used for training cadets. The Academy docks are located at the Buzzards Bay (within the Estuary) end of the Cape Cod Canal. The dock communities have a base of *Mytilus*, ulvoids, numerous crabs and *Ectopleura*, and a substantial amount of *Didemnum* sp.

Woods Hole Coast Guard (WHC), Woods Hole, Massachusetts

August 5, 2003 13:05 PM (http://www.uscg.mil/d1/units/gruwh/History.html)

The Coast Guard Station has been in existence since 1857, supporting buoys, lights and lightships. It served as the first base of the Ice Patrol formed after the sinking of the Titanic with the mission to conduct efforts to stop rumrunners and to prevent Germans from establishing weather stations. It continues to support navigation, marine safety, national defense and pollution prevention and response. The Coast Guard Station is a year-round, coastal marina located on a highly developed shoreline of the Vineyard Sound side of Cape Cod. Some floats were low in the water and difficult to reach. There was a high diversity of organisms, but deeper areas of the floats may be under-represented. Among the non-native fauna and flora were the introduced *Codium*, which was found growing on the docks, small *Balanus crenatus*, and numerous ascidians.

Bugula neritina, an introduced bryozoan, grew on seaweed. Photo credit: P. Dyrynda

F.L.Tripp and Sons, Inc. (TRM), Westport, Massachusetts

August 6, 2003 13:20 PM (http://www.fltripp.com/marina/index.shtml)

Tripp's marina is located in the Westport River and can accommodate boats up to 65 feet and with drafts of 10-12 feet. The wooden floating docks of this marina are over Styrofoam floats and in the water year-round within a tidal estuary in Buzzards Bay. The area has some natural shoreline with aquaculture areas nearby. The floats were covered with *Mytilus*, tunicates (*Botrylloides*, *Botryllus*, and *Didemnum*) and sponges; little attached macrophytes were present but numerous examples of drift algae were observed.

A heavily fouled propeller of a recreational boat that may transport organisms from one location to another. Photo credit: J. Pederson

Allen Harbor (ALH), North Kingston, Rhode Island

August 6, 2003 08:35 AM (http://www. risaa.org/newsletter/boat_ramps/allen_harbor.html)

Located within the North Kingston park system, Allen Harbor offers boaters an access ramp and provides a small dockage area for transient boaters. The floating docks are supported by Styrofoam floats, some with rubber bumpers and attached to wooden pilings. This is a small marina in the vicinity of a large automobile distribution facility. There was a high abundance of bryozoans, ascidians, a few mussels, and many *Crepidula fornicata*.

Newport Shipyard (NPS), Newport, Rhode Island

August 6, 2003 10:00 AM (http://www.newportshipyard.com/dockage.asp)

Newport Shipyard is one of the largest private marinas that we visited and it accommodates yachts over 80 feet in length. One of the oldest working yacht and shipyards in the region, Newport Shipyard is visited by boats from all over the world, especially the Caribbean, and it boasts a huge yacht yard for repairs. This site had *Laminaria*, *Grateloupia* and other attached macrophytes with *Electra pilosa* present on the *Laminaria*, as well as *Mytilus*, *Botrylloides*, and *Botryllus* as part of the base community. The introduced skeleton shrimp, *Caprella mutica*, was abundant at this location. The Newport Shipyard marina is a well-mixed region with high wave energy compared to most of the other sites.

Botrylloides growing on the native mussel *Mytilus edulis*. Photo credit: P. Erickson

Commercial and recreational boats were in this marina. Photo credit: G. Lambert

Brewer Yacht Yard at Mystic (BYY), Mystic, Connecticut

August 7, 2003 07:40 AM (http://www.byy.com/mystic/index.cfm)

Brewer Yacht Yard, located on the Mystic River, accommodates 222 slips with depths of 11 feet. The floats are covered with black plastic. The base community was primarily *Molgula manhattensis* and other ascidians, sponges, some *Mytilus*, and comparatively few algae.

Milford Yacht Club (MYC), Milford, Connecticut

August 8, 2003 09:05 AM (http://www.milfordyachtclub.com/index.php)

Located in Milford Harbor, an area where the shoreline is highly developed, Milford Yacht Club offers easy access to Long Island Sound. It has more than 70 slips and 60 dry storage spaces. Salinity was very low in parts of the marina; ascidians were rare. *Bowerbankia* was superabundant along with other bryozoans and barnacles, especially *Balanus eburneus*. *Mytilus* was common at the outer float. Diversity was low at this site.

Styela clava was covered with organisms at East Creek Marina. Photo credit: G. Lambert

Brewer Yacht Haven Marina (BYH), Stamford, Connecticut

August 8, 2003 10:55 AM (http://www.byy.com/stamford/index.cfm)

Located in an embayment with an adjacent tidal creek, Brewer Yacht Haven Marine Center features 630 seasonal slips. The shoreline is highly developed and altered with residential and commercial development in the vicinity. A salt marsh with drift *Fucus* and *Phragmites* was nearby. The community had a brown tide diatom on one side of the dock, and a layer of *Veggiota* (white filmy bacteria) in the anoxic surface layer. Juvenile examples of *Hemigrapsus* were very abundant in the fouling community. Solitary tunicates, *Crepidula*, and *D. lineata* formed the base; with *Molgula* very abundant at this site.

East Creek Marina (ECM), South Jamesport, New York

August 7, 2003 13:50 PM (http://www.longislandexchange.com/marinas.html)

This is a tidal estuary with a salt marsh located across from and adjacent to the marina. The marina has approximately 87 slips and is a year round facility. It was difficult to sample under the marina floats because the docks were so low and this community may be under sampled. *Molgula manhattensis* was very abundant on the Styrofoam floats, which also supported very large attached *Ulva* and shrimp; some *Geukensia* present in base. The abundance of *Gracillaria* suggests high temperatures and low salinity, and the absence of *Botrylloides* and presence of a few *Styela clava* also suggest low salinity. In general low biomass and low diversity were observed in this area.

Julian Smith III carefully collected flatworms hidden among algae growing at the top of floating structures. Photo credit: G. Lambert

Stirling Harbor Shipyard (SHS), Greenport, New York

August 7, 2003 12:15 PM (http://www.longislandexchange.com/marinas.html)

Located within a tidal estuary, Stirling Harbor Shipyard had wooden pilings and Styrofoam floats and some black plastic floats. The marina is a year round facility with approximately 185 slips. Dock M had been treated with antifouling paint and had only *Molgula* growing on it. *Molgula* was superabundant with a few mollusks and attached algae (e.g. *Ulva*) growing as the base community. Huge young of the year *Balanus eburneus* were present, but all were dead. A distinctive morph of *Molgula* with wider siphons and darker and tougher tunics was found.

South Street Seaport, Pier 16 (SSS), New York, New York

August 9, 2003 09:25 AM (http://www. Southstseaport.org/home.html)

We had great difficulty finding any floating docks in the New York City area. The South Street Seaport is both a tourist, recreational and commercial area. It has docked historic ships, vessels that provide rides, the Fulton fish market, and a nearby active port. Pier 16 was difficult to access and only a few people sampled the one floating dock that was accessible. In addition to the fouling community, a suspended cage was examined that contained *Crassostrea virginica*, *Mya arenaria* and *Molgula manhattensis*. The shoreline is extremely highly developed. On the floating dock *Mytilus* was abundant, as was *Bowerbankia*, botryllid ascidians, and *Ectopleura* at the edge. *Synidotea laevidorsalis* was found at this location and it was subsequently reported in Long Island Sound in 2004. Generally salinity in this area is around 20 psu, although it was 27 psu on the day we sampled.

An example of nine months' growth on plates deployed off floating docks showing introduced and cryptogenic tunicates and native mussel species. Photo credit: E. Sylvestre

Great Kills Park (GKS), Staten Island, New York

August 9, 2003 11:45 AM (http://www.cce.cornell.edu/seagrant/marinas/nycmarinas.html)

Great Kills Park is a private marina within the National Park but the adjacent shoreline is highly developed. The marina has over 350 slips. The abundant organisms on the floats were the sea squirt*Botryllus*, barnacles, and striped anemone *Diadumene lineata*, along with the bryozoan *Bowerbankia* and amphipod *Corophium*. *Molgula manhattensis* was abundant on floating lines. Abundance of algae was minimal, consisting mostly of *Ceramium strictum* (=*Ceramium deslongchampii*).

Snug Harbor Cultural Center (SNC), Staten Island, New York

August 9, 2003 13:40 PM (http//www.snug-harbor.org/main2.html)

A center for the arts, the Snug Harbor Cultural Center was formerly a seaman's retirement home. The Center is near the Staten Island Ferry terminal, adjacent to the Kill van Kull (major roads separate Snug Harbor Center from the shore). The Snug Harbor Cultural Center has a small dock that was built initially for ferry service, and which apparently was not suitable (because of strong currents and limited parking) and appears not to be used. The tidal current here is quite rapid and the area is influenced by freshwater in the spring. There was very heavy human influence in the vicinity with *Fucus* and green algae (probably *Enteromorpha* sp.) growing on riprap across from the docks. The floating docks were covered with *Microciona*, juvenile *Mytilus* and barnacles, andfeathery hydroids, *Botryllus schlosseri*, *Molgula manhattensis* and *Hydractinia*. Sampling effort may have been less intense here because the dock was small and high waves made sampling difficult.

Scientists examined algae, bumpers and floats at South Street Seaport, New York City. Photo credit: P. Dyrynda

APPENDIX II

Participant Name	Affiliation	Area of Interest
Field Team		
Robert A. Bullock	University of Rhode Island	Molluscs
James T. Carlton	Williams College-Mystic Seaport	Ombudsman
Jennifer Dijkstra	University of New Hampshire	Graduate Student
Nicole Dobroski	Williams College-Mystic Seaport	Recorder
Peter Dyrynda	University of Wales Swansea	Sponges, Bryozoans
Ryan Fisher	UMass Dartmouth & Salem State College	Polychaetes, Nematodes
Larry Harris	University of New Hampshire	Ombudsman, Lab
Niels Hobbs	University of Rhode Island	Amphipods, Isopods
Gretchen Lambert	U. Washington Friday Harbor Labs	Tunicates
Charles Lambert	U. Washington Friday Harbor Labs	Tunicates
Eric Lazo-Wasem	Yale University	Amphipods, Isopods
Arthur Mathieson	University of New Hampshire	Phycologist
Leo McKillop	University of New Hampshire	Research Assistant
Maria-Pia Miglietta	Duke University	Hydroids
Judith Pederson	MIT Sea Grant College Program	Ecologist, Co-organizer
Jan Smith	Mass Bay Estuary Program	Co-organizer
Julian Smith III	Winthrop University	Flatworms
Becca Toppin	University of New Hampshire	Research Assistant
Megan Tyrrell	MA Coastal Zone Management	Recorder, Dock Manager
Logistic Support Team		
Jason Baker	MA Coastal Zone Management	Data Management
Laura Bartovic	NY/NJ Estuary Program	Logistics at NY/NJ
Laura Bavaro	Peconic Estuary Program	Logistics at LIS
Beverly Bayley-Smith	ME Casco Bay Esturary Program	Logistics at ME
Diane Brousseau	Fairfield University	Lab at CT, Scientist
Marnita Chintala	USEPA: AED	Logistics at RI, Lab
Chris Deacutis	RI National Program	Logistics at RI
Michael DeLuca	Peconic Estuary Program	Logistics at LIS
Mike Doane	ME Casco Bay Estuary Program	Logistics at ME
Lee Doggett	ME Dept. Marine Resources	Logistics at ME
Jennifer Drociak	NH Coastal Zone Management Program	Logistics Support
Jennifer Hunter	NH Estuaries Program	Logistics in NH
Jane McClellan	US Fish & Wildlife/LIS Study	Logistics at NY
Robin Seeley	Cornell University	Observer, Scientist
Brian Smith	Great Bay NEERS	Logistics in NH
Sally Soule	NH Coastal Zone Management Program	Logistics in NH
Mark Tedesco	Long Island Sound Study	Logistics at NY
Phil Trowbridge	NH Estuaries Program	Logistics in NH
Tracy Warncke	Buzzards Bay NEP	Logistics in MA
Cathy Yuhas	NJ Sea Grant Extension Program	Logistics at NY/NJ
Brenda Zolitsch	ME Casco Bay Estuary Program	Graduate Intern

A floating dock was lifted to enable scientists to sample organisms at Portland Yacht Services. Photo credit: G. Lambert

Megan Tyrell and Neils Hobbs recorded species observed on the dock. Photo credit: G. Lambert

APPENDIX III

EQUIPMENT USED IN RAPID ASSESSMENT SURVEYS

Field Equipment

Ice chests
Large, leak proof plastic bags
Whirl pack bags
Gel ice packs/ice
Coolers


After sampling on the floating docks, Arthur Mathieson collected algae from the intertidal area to add to his extensive New England collection. Photo credit: P. Dyrynda

Hand scrapers
Long-handled spatulas
Dissecting equipment
(Forceps, dissecting needles, pipettes)
Plastic containers, with/without lids
Buckets
Dishpan sized pans
Long handled nets
Aquarium nets

Secchi disk
GPS unit (2)
Dissolved oxygen meter (2)
Thermometer (2)
Refractometer (2)

Dock manager field sheets
Field notebooks
Labels
Museum jars

Laboratory Equipment and Materials

Dissecting scopes
Microscopes
Light sources (preferable fiber optics)
Dissecting equipment
Glass bowls
Petri dishes
Graduated cylinders
Slides
Cover slips

Sea water
Alcohol
Formalin
Special fixatives

Field guides
Keys
Monographs

Herbarium materials

Museum jars
Labels

Hoods
Sinks
Bench space

A plastic bag filled with organisms was returned to the laboratory for further identification and archived for future reference. Photo credit: G. Lambert

Jim Carlton and Ryan Fisher displayed kelp. Photo credit: G. Lambert

Scientists studied field samples at the Massachusetts Maritime Academy docks. Photo credit: P. Dyrynda

Peter Dyrynda examined a small specimen with a magnifying glass and discussed his findings with Charles Lambert. Photo credit: G. Lambert

Front cover images:

background marina image, P. Dyrynda

Left: *Ciona intestinalis* is a solitary, cryptogenic sea squirt characterized by a yellow band around its incurrent and excurrent siphons. Photo credit: P. Erickson

Center: *Sagartia elegans*, a small European anemone was found at only one location in the 2000 and 2003 rapid assessment surveys. Photo credit: J. Pederson

Right: The Asian shore crab (*Hemigrapsus sanguineus*). Photo credit: P. Erickson

Back cover images:

background marina image, P. Dyrynda

Left: Two compound tunicates, *Botryllus schlosseri*, the golden star tunicate, and *Botrylloides violaceus*, the orange sheath tunicate compete for space. Photo credit: P Erickson

Center: *Codium fragile* ssp. *tomentosoides* at Salem, Massachusetts. Photo credit: P. Erickson

Right: The common New England intertidal periwinkle, *Littorina littorea*, was introduced to North America from Europe in the 19th century. Photo credit: J. Pederson

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